3D numerical modeling of sediment handling techniques in a hydro power reservoir

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INTRODUCTION

Sedimentation of small as well as large water storage reservoir has become a major issue. Due to the fact that we observe a 1% decrease of reservoir volume every year due to sedimentation and that the largest part of the reservoirs have been built between 70 and 40 years ago, many HPPs are confronted with the threatening scenario that soon the active storage and therefore their lifetime is dramatically diminished. Due to the aforementioned combinations, active and sustainable sediment management has become the last option to retain or preferably enlarge the left-over reservoir volume. There are several options for a sustainable sediment handling, each for a different boundary condition, which must be evaluated carefully in order to be successful. For a successful choice, design and conduction of a sediment handling technique, usually a physical scale model will be conducted. However, physical scale may have some disadvantages which can be overcome by using a numerical model. In additional, the results of the numerical models can be used to assess designs which can be investigated further in physical models.

This study attempts to use a 3D numerical model to serve as an additional source of alternatives in finding the right sediment handling techniques in reservoirs with high discharges of suspended and bed load. The goal is to simulate different flow scenarios in order to gain insights in the current situation as well as to have a better understanding of the physical processes in the reservoir. This will support and have positive influence in the sustainable design of sediment handling techniques.

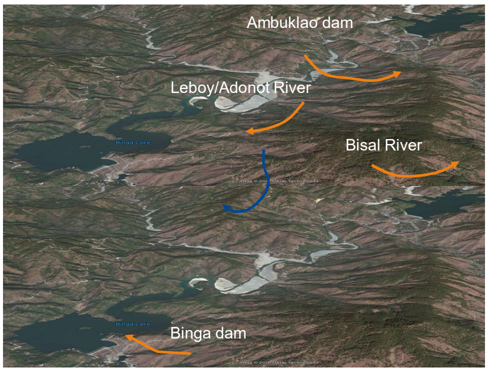

Figure 1: Aerial photo of Ambuklao and Binga reservoir

CASE STUDY & METHOD

Binga reservoir (Figure 1) in Philippines is taken as a case study. This reservoir is the storage for 140 MW hydropower plant. The reservoir had an initial storage volume of 95.1 mill.m³ that has reduced to 22% since its commissioning in 1960. Currently, several sediment management techniques are being scrutinized for sustainable operation of the project in the future.

A 3D CFD model (SSIIM) has been used here to simulate the flow pattern in the reservoir for different flow and geometric scenarios at different operational water level. The two flow scenarios at 1000 m³/s and 5500 m³/s corresponds to the flood with the return period of 2 and 100 years, respectively. As far as it concern the geometrical scenarios, a bypass channel and submerged spur dikes at different locations of the reservoir to divert flow bed load were studied. One scenario is additionally simulated with a higher operational water level to illustrate how small the sediment transport capacity is if the water level is not adapted for large flow events. different reservoir water elevations were also simulated.

The computed bed shear stress in all the scenarios is used as an indicator to estimate the bed load transported capacity along the reservoir.

RESULTS

Hydraulic simulation with flow 1000 m³/s is presented in Figure 2. Figure 2(a) shows the flow pattern for HRWL (575.7m a.s.l.), corresponding to the actual operations rules for a flood with a 2 years return interval. The results show that the flow velocity is around 1m/s in the main channel with highest velocity being 1.4 m/s at the bend at the inlet of the reservoir. The bed shear stress shows to be around 3.5 N/m² (light green) in the main channel of the incoming flow. Figure 2(b) shows an increasing bed shear stress of about 10 times with the lower operational water level for the same discharge. The reader has to compare the blueish area (50-70 N/m²) with the green area in Figure 2(a). The local extreme values for this configuration are occurring because at this location, the free surface meets the head of reservoirs, the beginning of the backwater zone. The LRWL is at 568 m a.s.l.

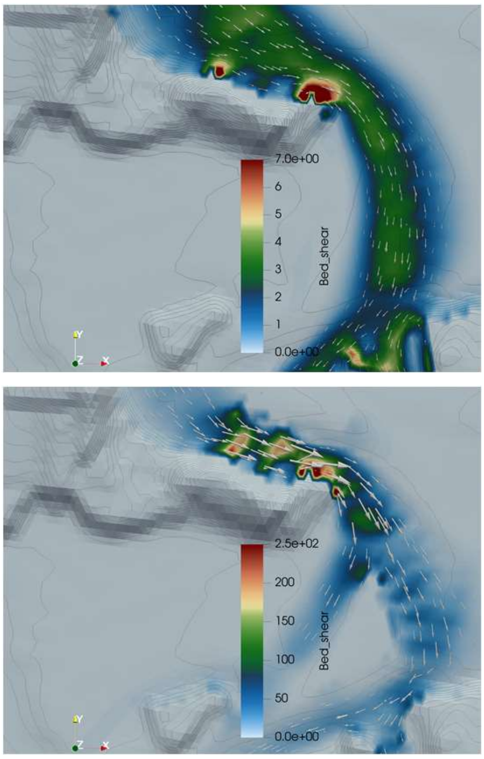

Figure 2: Bed shear stress and velocity vectors for 1000 m³/s, a) high water level (575.0 m a.s.l.), b) low water level (568.0 m a.s.l.)

Hydraulic simulations with flow 5500 m³/s with different geometrical configurations are presented in Figure 5. The idea behind introducing a channel to the reservoir is to investigate extraction of bed load through this channel where a sediment bypass tunnel (SBT) is connected to. The simulated water elevation is at full gate opening, 575.66 m a.s.l. The average flow velocity is about 6 m/s in the river reach and the bed shear stress is about 150 N/m². The bed shear stress increases to about 250 N/m² at the exit of the bend.

In the configuration displayed in Figure 2(b), a bypass channel of 10m width is modelled on the right bank in the river reach. At the location of the channel inlet, the velocity decreases to 4.5 m/s. The bed shear stress at the inlet of the channel also decreases to about 75 N/m² and within the channel, it is about 100 N/m².

In the configuration displayed in Figure 2(c), a groyne is placed almost perpendicular to the flow. This measure is supposed to increase the flow through the bypass channel. The flow velocity in the channel increases to 6 m/s whereas decreases d/s of the groyne. The bed shear stress at the inlet of the channel increases to 100 N/m² than the Scenario b.

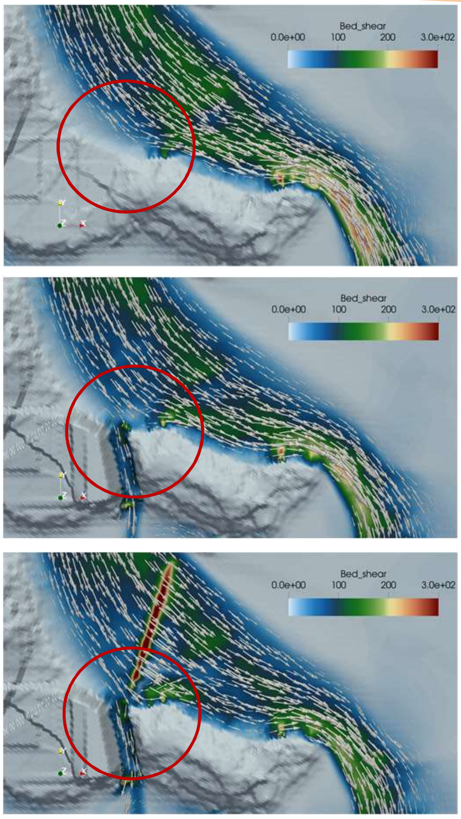

Figure 3: Hydraulic simulation for 5500 m³/s with full open spillway gates, a) actual situation, b) bypass channel, c) with bypass channel and groyne

Figure 4 shows another design with submerged spur dikes which shall accelerate the flow and increase the bed shear stress in order to transport the sediments all the way to the spillway. This scenario could represent a flushing operation where the sediments are either transported over the spillway or to a SBT located close to it.

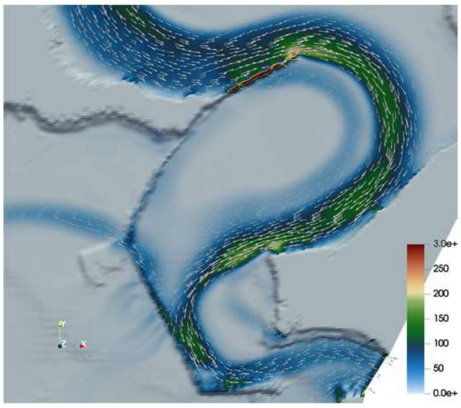

Figure 4: Hydraulic simulation for 5500 m³/s with full open spillway gates and a groynes to divert flow to gates

CONCLUSION

Different geometrical configurations for different discharges with fully opened gates are simulated to investigate the possibility to extract bed load at different location in the reservoir. The results show that this is fully possible with geometrical changes and changes in the operational rules. Further investigation on the detailed design and real bed load simulation are necessary to confirm the outcome of this study.

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